Impacts of Land Cover/Land Use Changes in Coastal Tropical Regions under a Changing Environment

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  - PREVIOUS LCLU CHANGES IMPACT STUDIES
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  - PRELIMINARY RESULTS
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    - LCLU CHANGES & CLIMATE CHANGE IMPACT
- PROJECT TIMETABLES
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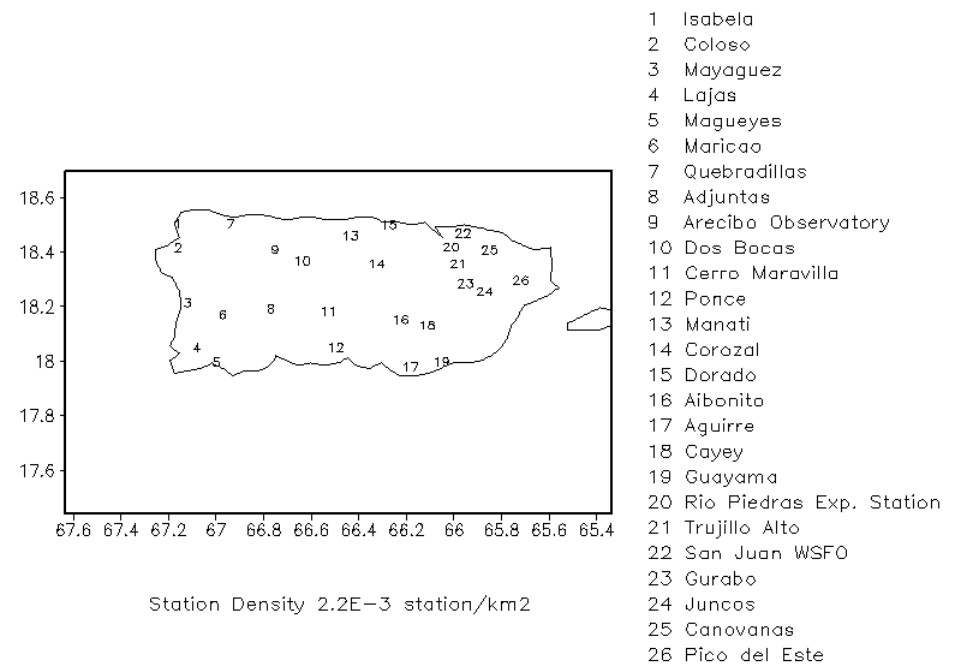
LCLU Changes Studies in Tropical Regions

- Tropical coastal areas represent an interesting case in which global, regional and local effects converge, via the combination of general atmospheric circulations, large urban centers, and pristine rain forests.

- This unique combination of factors puts the vast majority of tropical regions among the principal biodiversity hotspots in the world.

- These tropical regions, with a great amount of coastlines and urban centers close to them, require a focused attention in all aspects of the ecosystem structure and life.

LCLU Changes Studies in Tropical Regions

- UHI identification in tropical cities have typically used temperature difference from ground weather stations and remote sensing satellite information.

- These studies established both the existence of strong UHI in major tropical cities, many of which are coastal, and some very interesting temporal and spatial patters of each UHI.

- UHI effects and climate impact studies due to LCLU changes have been recently performed with combined observational and numerical components.

- Some of the drawbacks of these studies is that the modeling is simplified and not all effects are included, analyzed or separated.

The Case of the SJMA, Puerto Rico

o   Puerto Rico offers a great opportunity for LCLU change impact studies because:

•   The close proximity of the San Juan Metropolitan Area (SJMA), the Luquillo Experimental Forest (LEF), and the Central Mountain range

•   Evidence of combined global and local effects on regional climate

•   Interesting historical LCLU practices (agriculture, urbanization, deforestation, reforestation)

•   The recently drafting and implementation of the Puerto Rico Land Use Plan


1   Isabela
2   Coloso
3   Mayaguez
4   Lajas
5   Magueyes
6   Maricao
7   Quebradillas
8   Adjuntas
9   Arecibo Observatory
10 Dos Bocas
11 Cerro Maravilla
12 Ponce
13 Manati
14 Corozal
15 Dorado
16 Aibonito
17 Aguirre
18 Cayey
19 Guayama
20 Rio Piedras Exp. Station
21 Trujillo Alto
22 San Juan WSFO
23 Gurabo
24 Juncos
25 Canovanas
26 Pico del Este

Stations used to Construct the Observed Puerto Rico Climatology

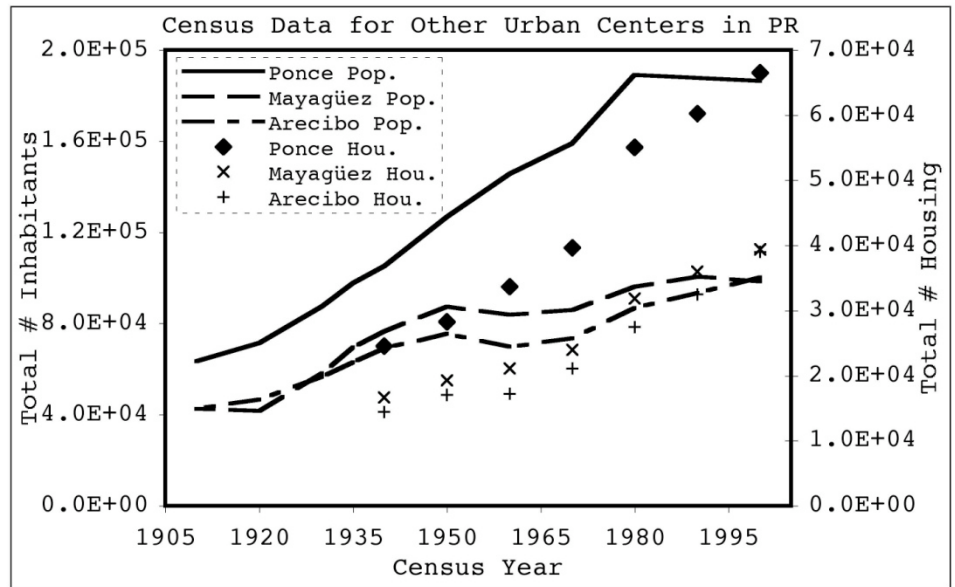# Data Analysis: Historical Temperature Data in Puerto Rico 1950-2006

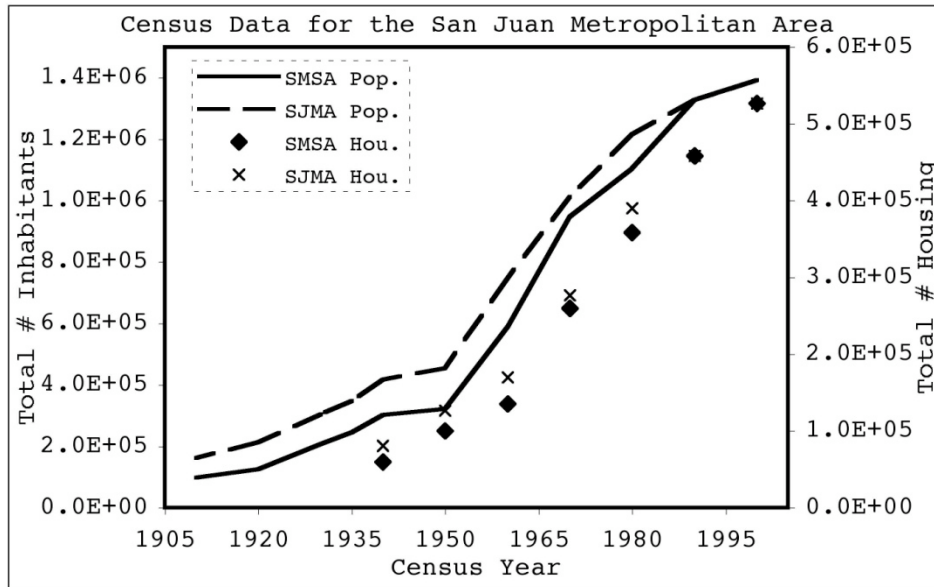Average Max & Min Temperatures in Puerto Rico (1950-2006)

Average Max & Min Temperatures in the SJMA (1950-2006)
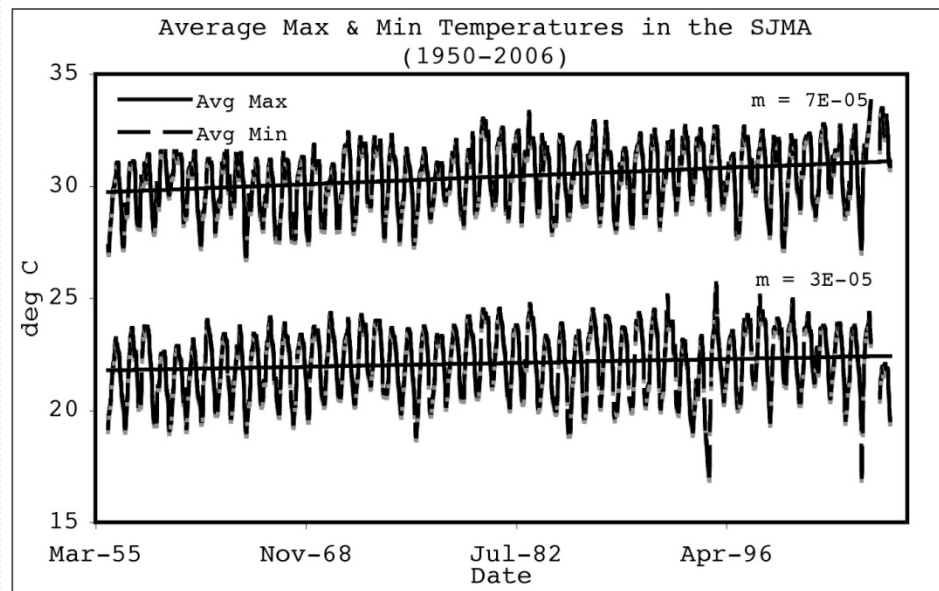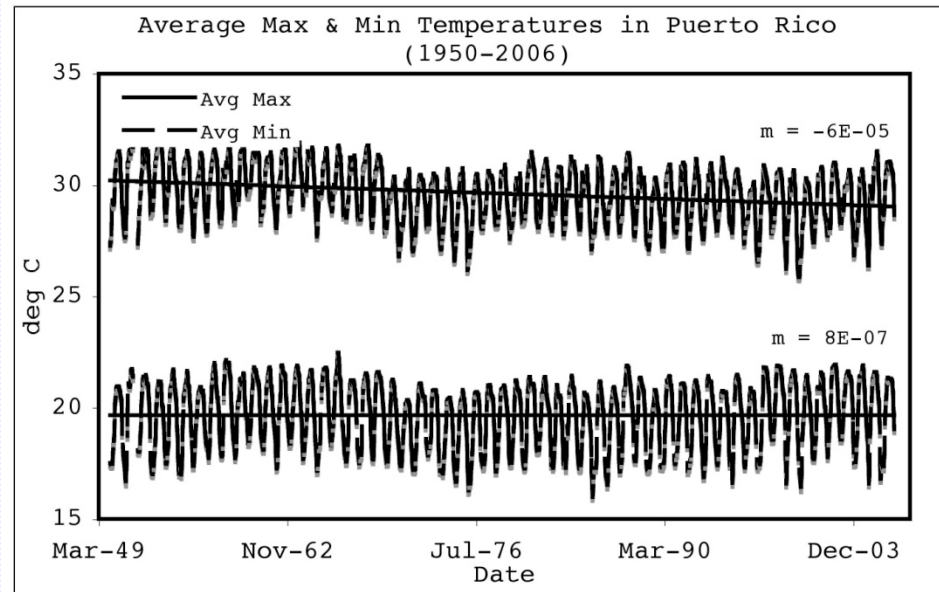
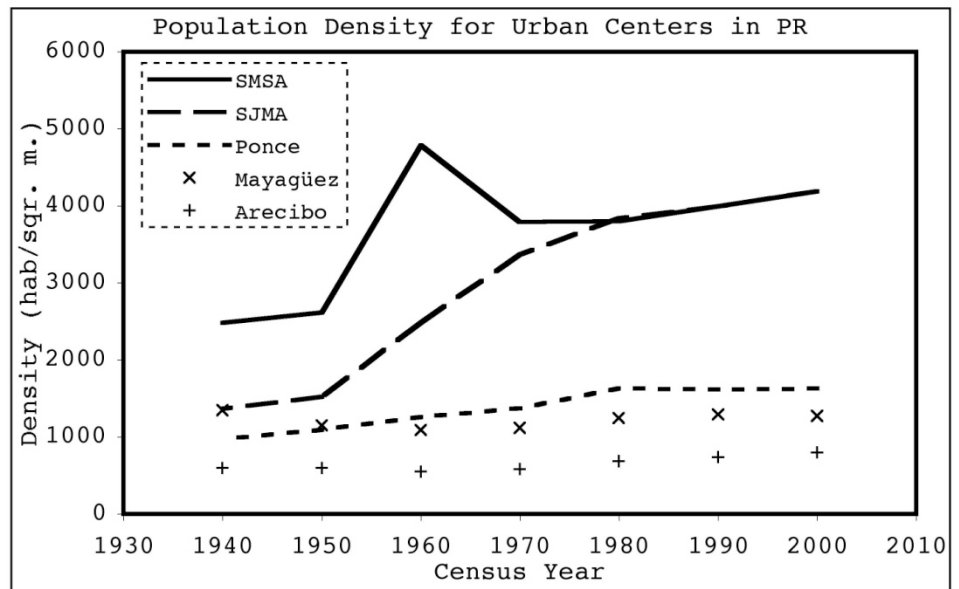# Population Dynamics in Puerto Rico: Urban & Rural Information
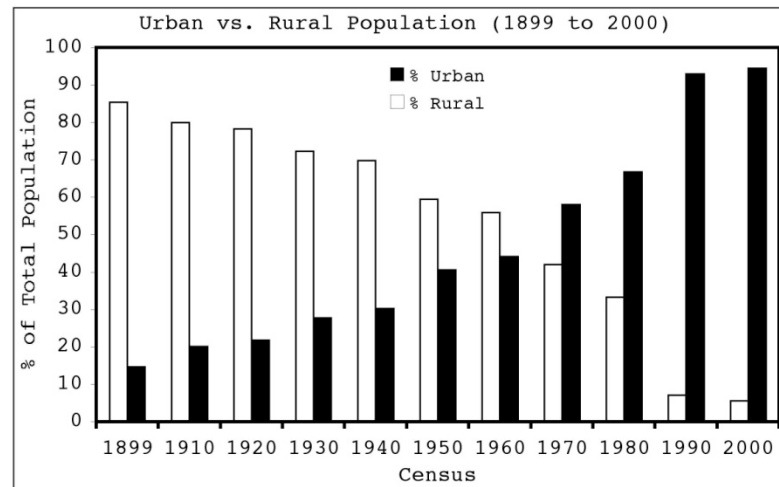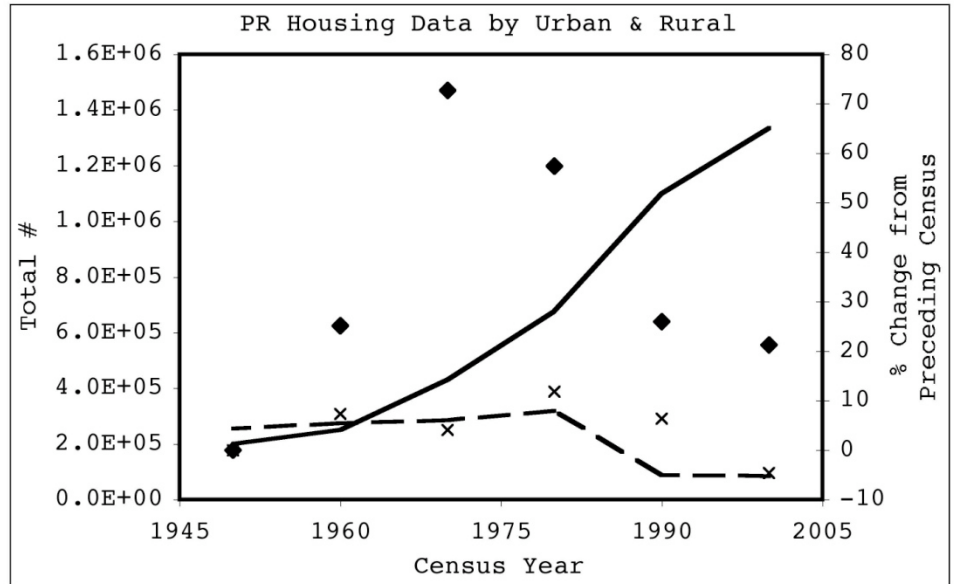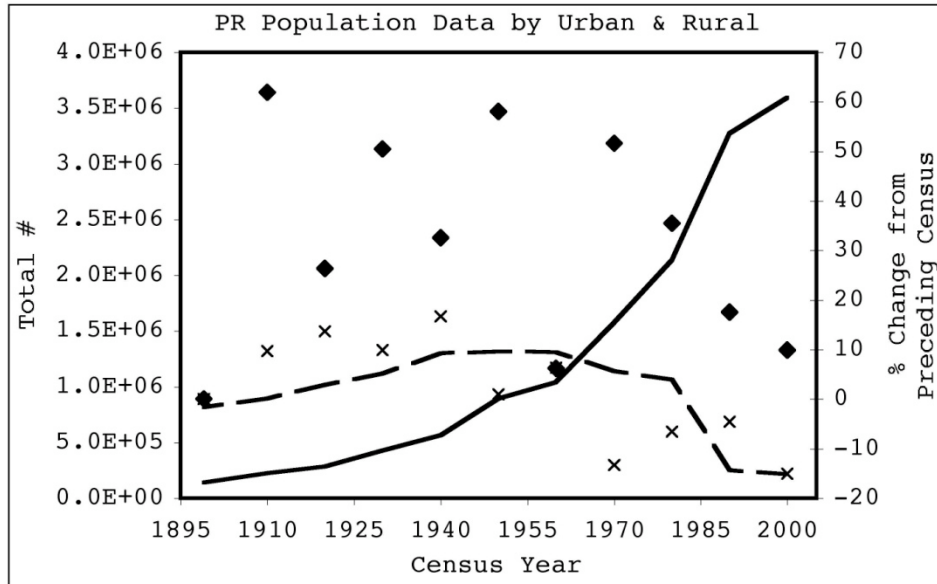
The San Juan Metropolitan Area (SJMA) & Other Principal Urban Centers in PR


Standard Metropolitan Statistical Area (SMSA) as defined by the U. S. Census Bureau, its boundaries change with time.

San Juan Metropolitan Area (SJMA), keeping the boundaries fixed with the current municipalities
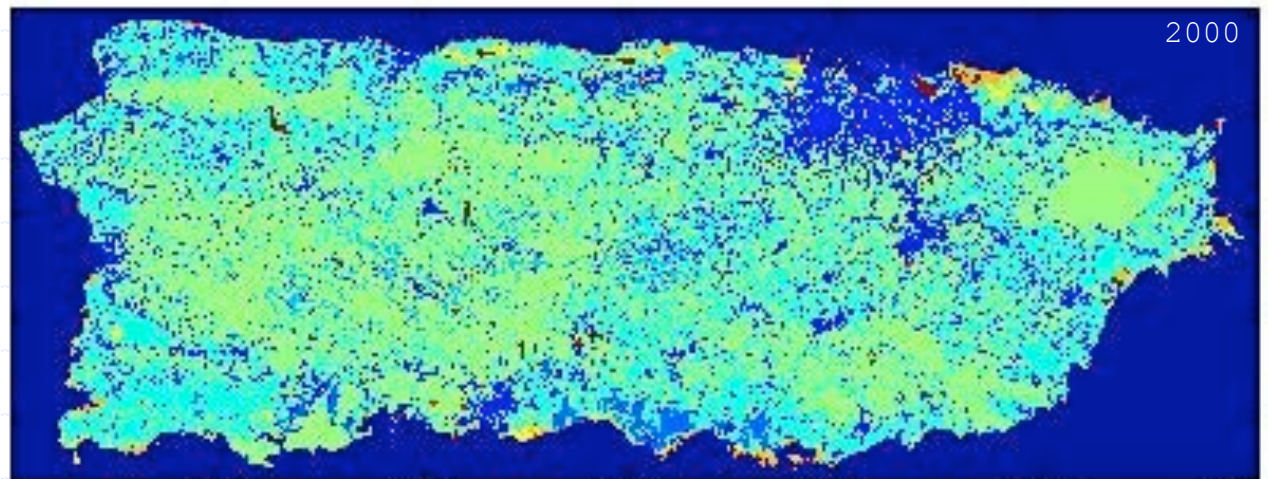
Original LCLU Specifications 1951 & 2000

From Kennaway, T., and E. H. Helmer, 2007: The Forest Types and Ages Cleared for Land Development in Puerto Rico. *GIScience and Remote Sensing,* **44**, 4, 356-382.
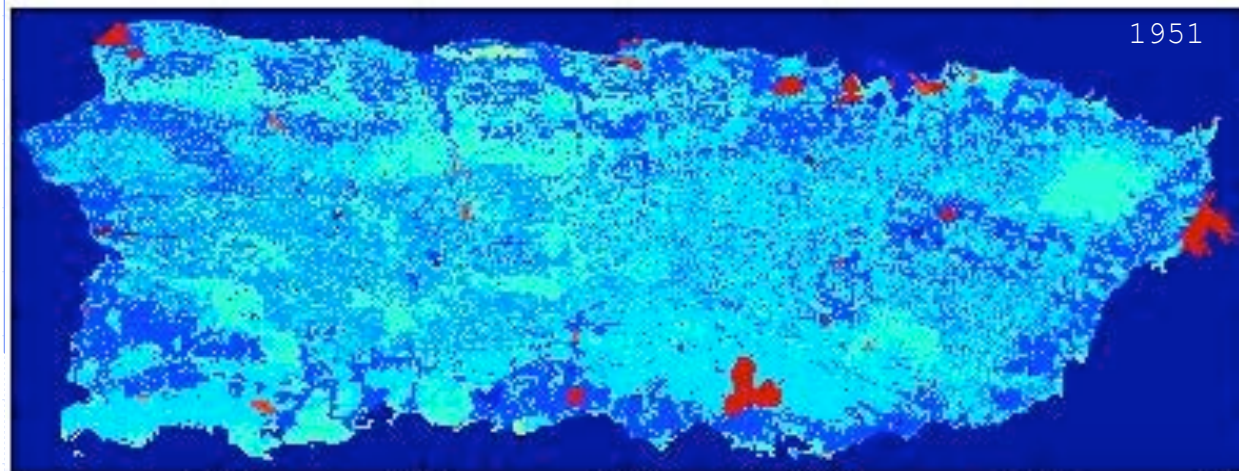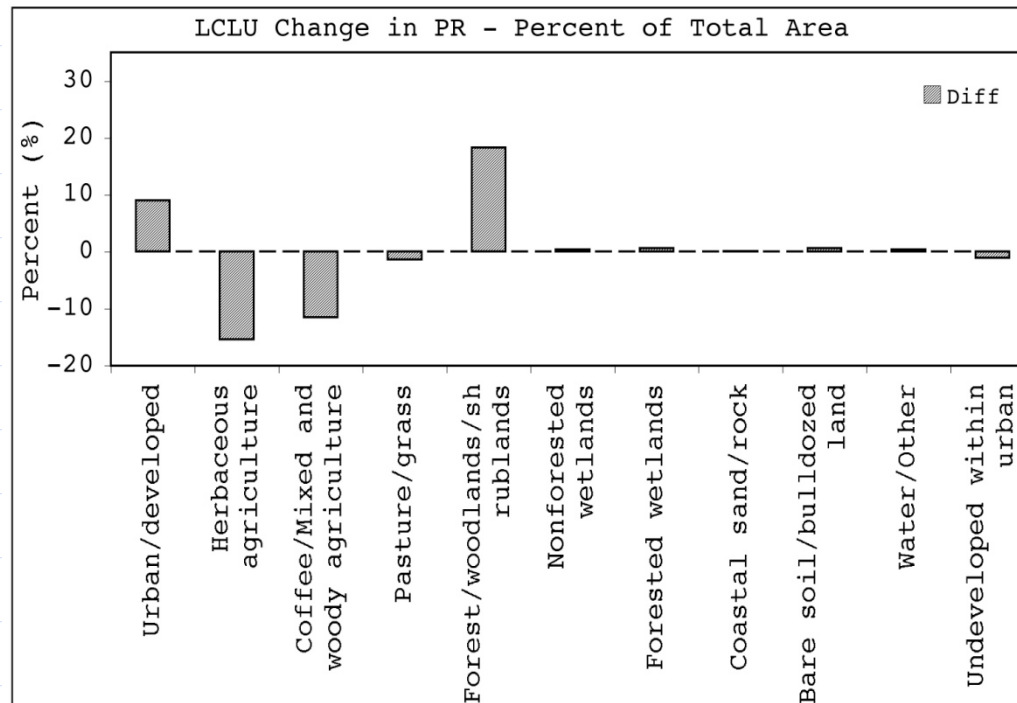
1951

Original 1951 hard copy map:

Brockman, V. M., 1952

2000

Description	class
Background/water	0
Urban/developed	1
Herbaceous agriculture	2
Coffee/Mixed and woody agriculture	3
Pasture/grass	4
Forest/woodlands/shrublands	5
Nonforested wetlands	6
Forested wetlands	7
Coastal sand/rock	8
Bare soil/bulldozed land	9
Water/Other	10
Undeveloped within urban	11

LCLU Specifications - Puerto Rico

LCLU Change in PR - Percent of Total Area

Description	class	1951	2000	Diff
Background/water	0			
Urban/developed	30	1.21	10.23	9.02
Herbaceous agriculture	8	16.11	0.78	-15.33
Coffee/Mixed and woody agriculture	12	13.06	1.55	-11.51
Pasture/grass	27	25.78	24.41	-1.38
Forest/woodlands/shrublands	3	12.47	30.78	18.31
Nonforested wetlands	16	0.15	0.58	0.43
Forested wetlands	19	0.00	0.64	0.64
Coastal sand/rock	26	0.00	0.13	0.13
Bare soil/bulldozed land	27	0.00	0.59	0.59
Water/Other	1	0.25	0.66	0.41
Undeveloped within urban	7	1.00	0.00	-1.00

Puerto Rico, Island-wide
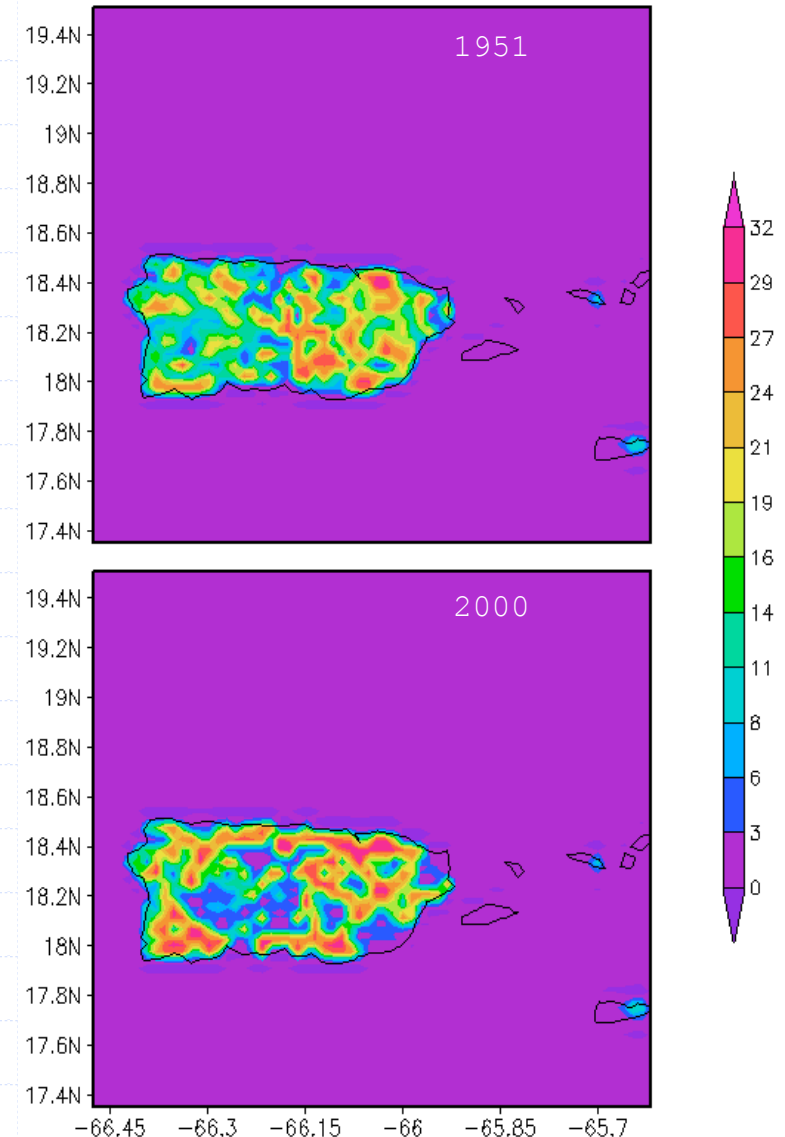
LCLU Specifications – Northeastern PR

LCLU Change in NE PR – Percent of Total Area
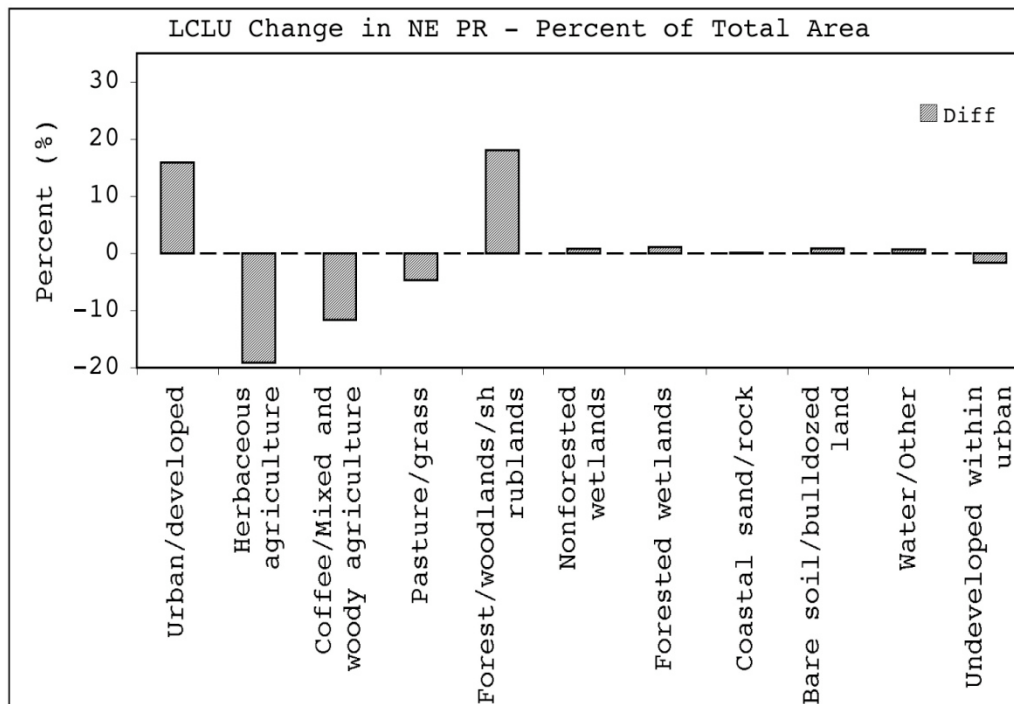
Description	class	1951	2000	Diff
Background/water	0			
Urban/developed	30	1.92	17.81	15.89
Herbaceous agriculture	8	19.19	0.09	-19.10
Coffee/Mixed and woody agriculture	12	12.38	0.76	-11.62
Pasture/grass	27	33.73	28.99	-4.74
Forest/woodlands/shrublands	3	9.37	27.43	18.06
Nonforested wetlands	16	0.00	0.76	0.76
Forested wetlands	19	0.00	1.08	1.08
Coastal sand/rock	26	0.00	0.14	0.14
Bare soil/bulldozed land	27	0.00	0.91	0.91
Water/Other	1	0.23	0.93	0.70
Undeveloped within urban	7	1.71	0.00	-1.71
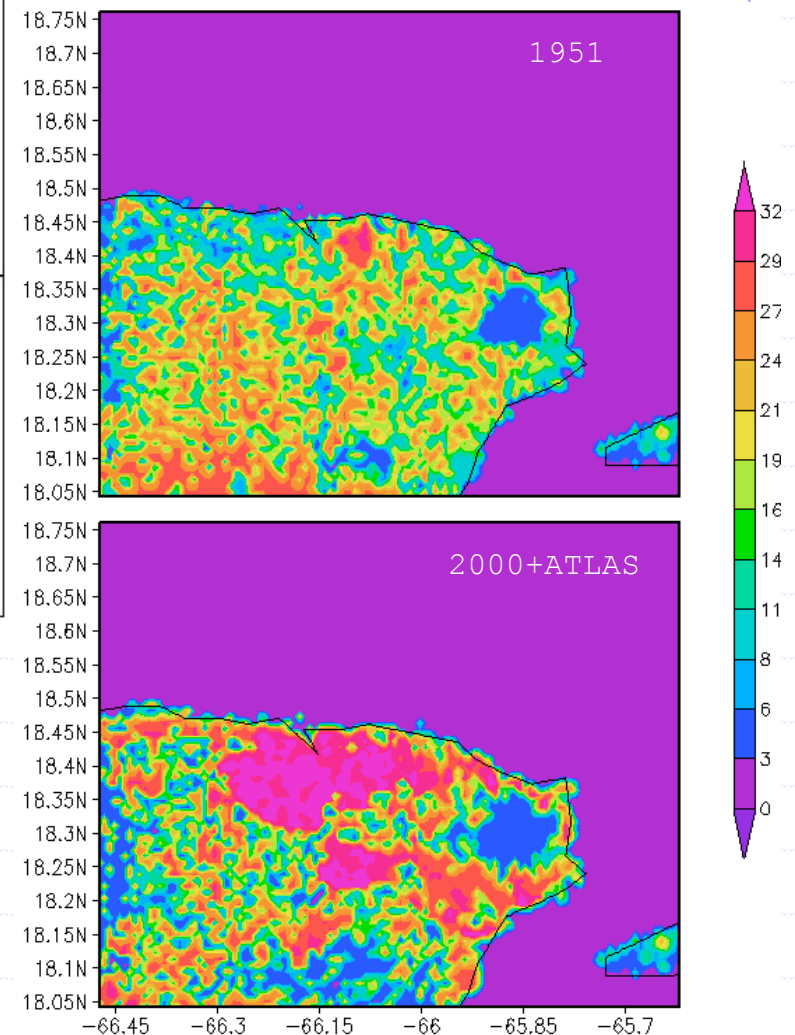
LCLU Specifications
Urban Comparison (1951 vs. 2000)
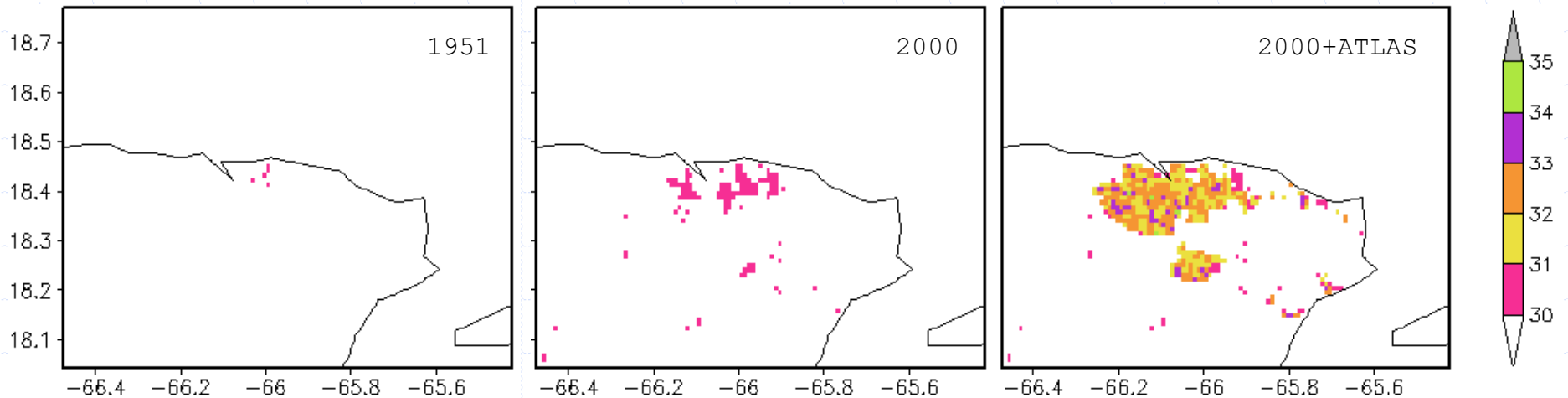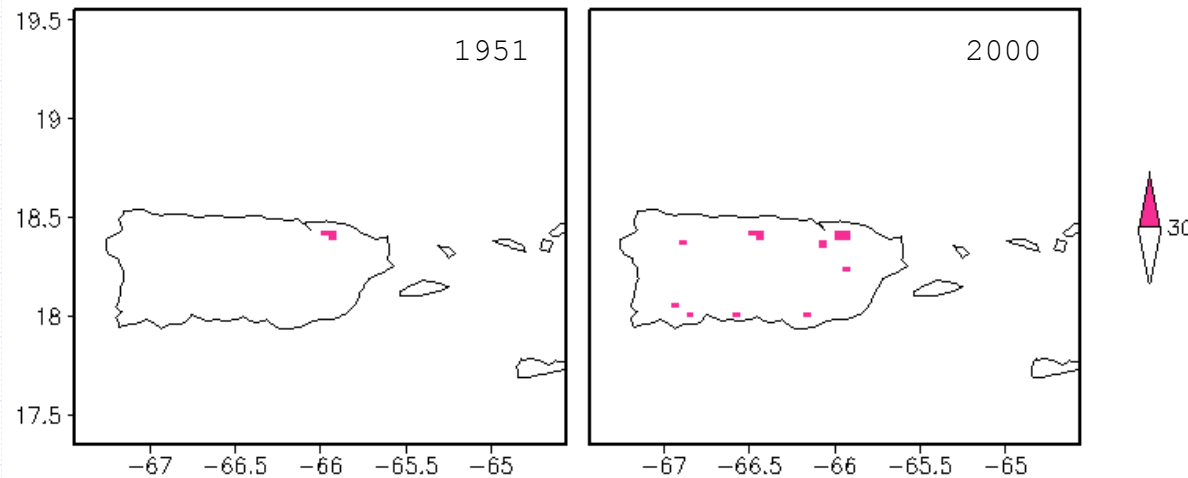
Fundamental Research Questions

An attempt to bridge the knowledge gap in the matter of the impact of LCLU changes in tropical coastal regions in a changing environment will be made by trying to answer the following questions:

1. What is the relative effect of historical LCLU changes on the climate of tropical coastal regions?

2. What is the relative climatic impact of global climate change in tropical coastal regions?

3. Under these conditions of LCLU and global climate change, what is the combined effect in tropical coastal regions?

Urban/Vegetation Canopy Modeling

To capture the most relevant effects caused by the presence of heterogeneous surfaces in the domain [i. e. a large urban center (SJMA), the tropical montane cloud forest (LEF), and low elevation coastal plains (pasture/mix farming)], a general energy budget modeling scheme, in conjunction with an adaptation of the atmospheric model chosen for this work, has to be use that will allow us to reach our research goals.

Additional Fundamental Research Question

Analyzing possible ways of how to deal with some of the remaining *Thermal* effects of cities on the urban boundary layer, a new questions regarding surface parameters and heat fluxes arises

4. Can parameters such as the thermal response number (TRN) and the Bowen ratio be used as indicators of environmental change?

Methodology / Numerical Experiments

In order to answer these questions a series of numerical atmospheric simulations are proposed to separate the signals of LCLU change and global climate change. The Regional Atmospheric Modeling System (RAMS) will serve as the main research tool.

General Model Configuration			
	Grid 1	Grid 2	Grid 3
$\Delta x = \Delta y$	25km	5km	1km
vertical	σ-coordinate $\Delta\sigma$ = 30mts near sfc until $\Delta\sigma$ = 1km, model top at ~25km		
CPU time	Approximately 5 to 6 days for a 30-day simulation		
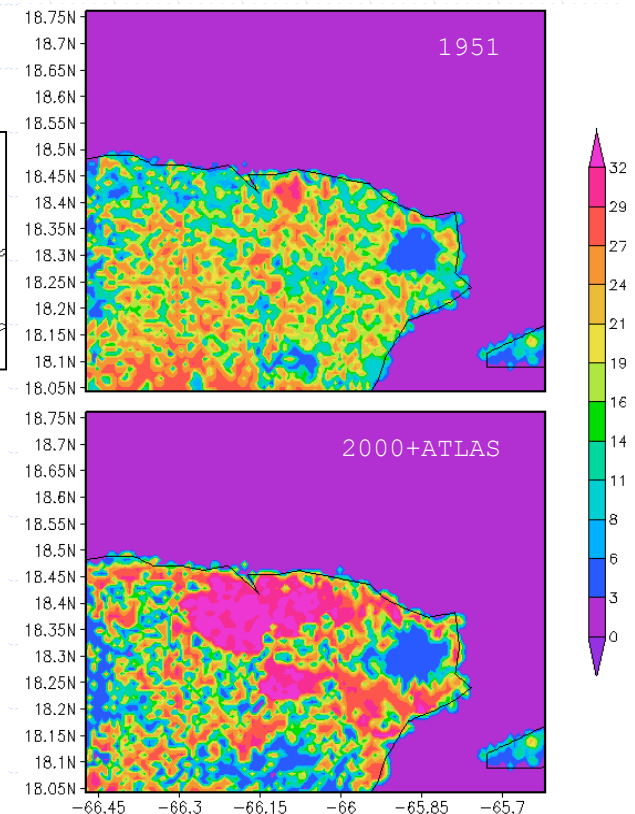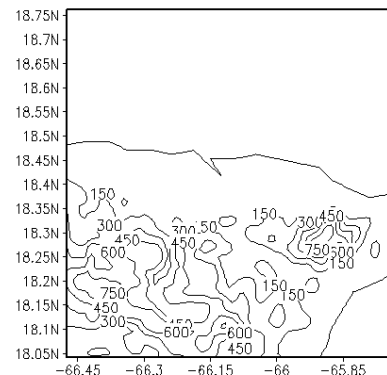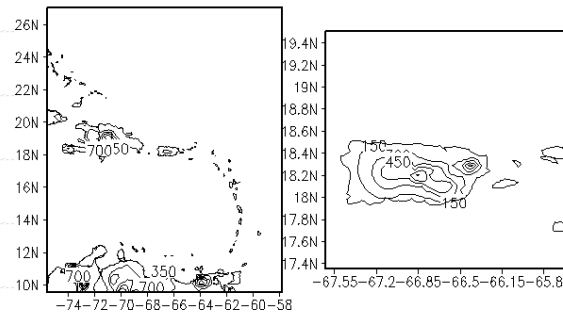
Model grids w/ topography and surface characteristics for the two scenarios analyzed

# Table 1: Numerical Experiments Matrix

Run ID	LCLU	Driving Conditions**	Questions
Present1*	ATLAS	Present Clim. & GHG concentration	1, 2, 3, 4[+]
Present2	ATLAS	Past Clim. & GHG concentration	2, 3, 4[+]
Past1	PNV	Present Clim. & GHG concentration	1, 3, 4[+]
Past2	PNV	Past Clim. & GHG concentration	3, 4[+]

*   Control run

**   The timeframe for the present and past climatologies will be selected as to reduce the influence of the El Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) on the Caribbean Early Rainfall Season (ERS) climate, as identified by previous studies, and in accordance with historical LCLU changes.

[+]   The fourth question arose while analyzing the urban/vegetation canopy modeling parameterization and is presented later.

Modeling Results Validation: Present Climatology (PRESENT1 vs. Observations)
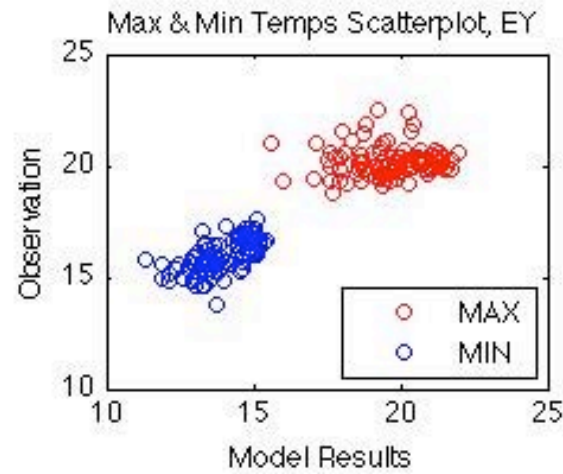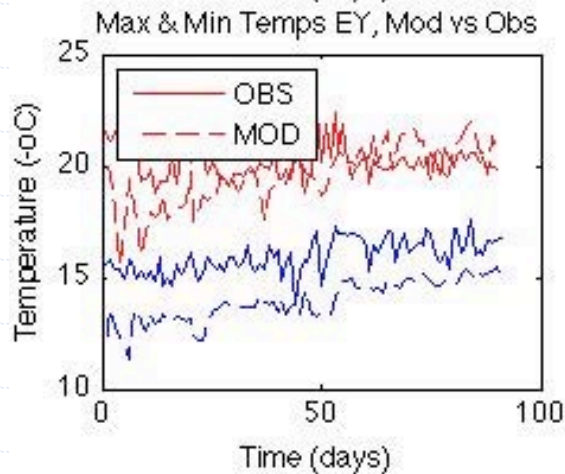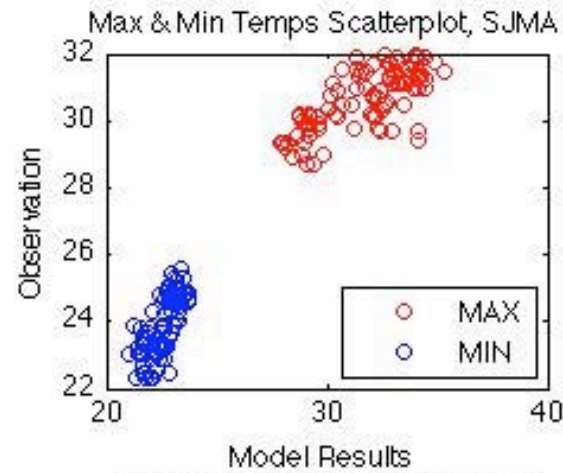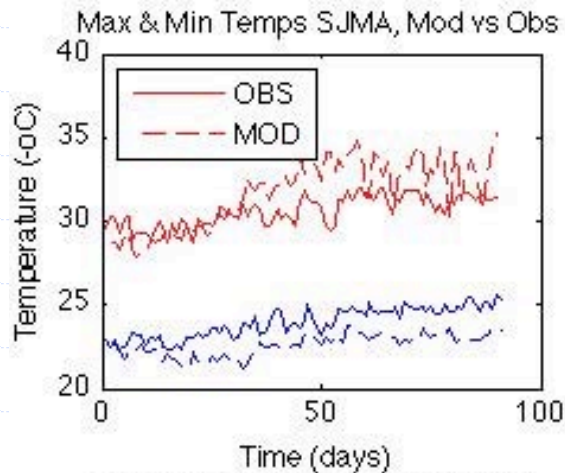
Correlation Coefficients
MAX_TEMP SJMA: 0.6706
MIN_TEMP SJMA: 0.7288
MAX_TEMP EY: 0.1113
MIN_TEMP EY: 0.6593

95% Intervals
0.5154   0.7875
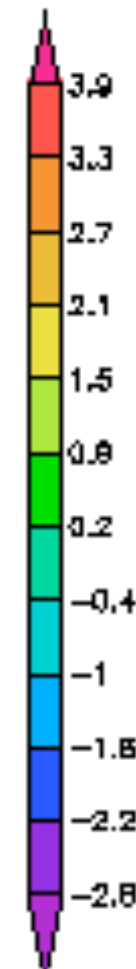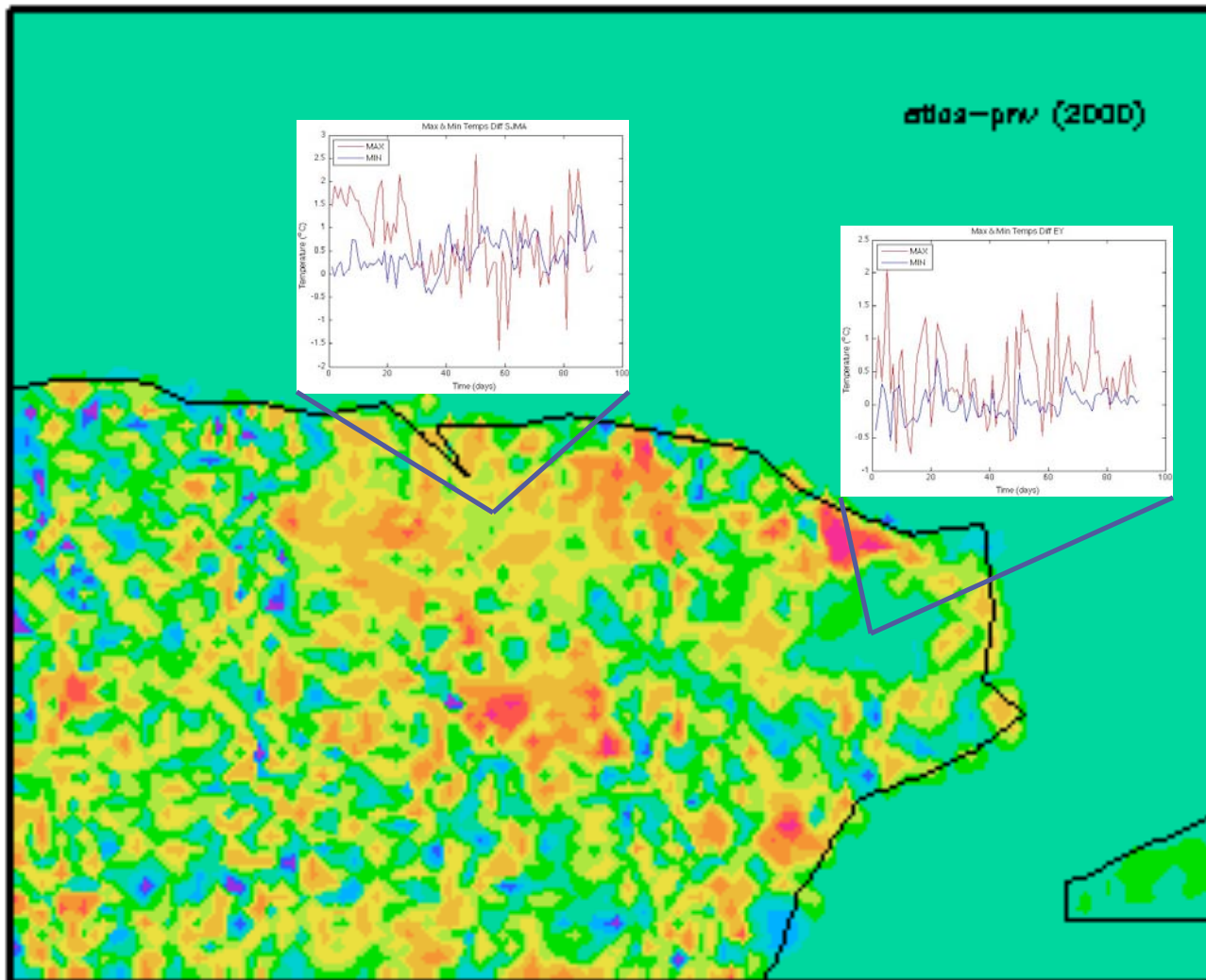0.6524   0.7863
-0.0999   0.3229
0.5463   0.7527

- Coefficients are calculated using the Spearman Rank Correlation

- 95% confidence interval formed using a 10,000 bootstrap sample

Preliminary Results:
ERS 2000, LCLU Change Impact

Temperature Difference
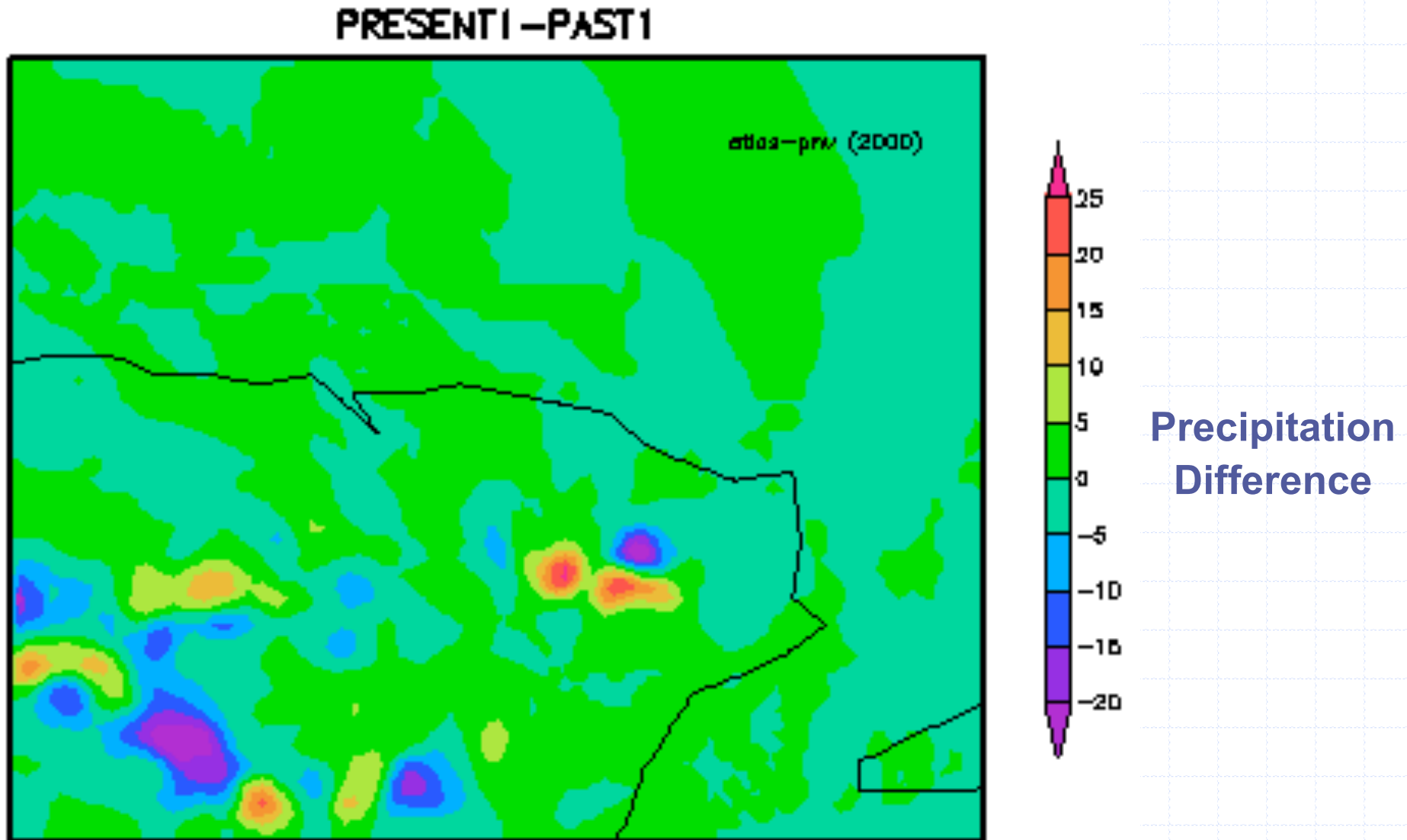
Statistical Significance

	SJMA	EY
MAX	2.6438	2.1813
MIN	3.6521	0.1585

Preliminary Results:
ERS 2000, LCLU Change Impact

PRESENT1–PAST1

Precipitation Difference

Summary/Conclusions

Summary:

o Evidence of climate changes in the tropical coastal area of study, as reflected by asymmetric warming.

o Historical land use changes for the case study include population growth, mobility to urban areas, and reforestation.

o Environmental impacts attributed to LCLU may have been (in reality) consequence of combined effects GHG+LCLU.

o LCLU impacts reflect in surface temperature increases.

o Forestation has an apparent mitigating effect to UHI & Global Warming effects.

Future Tasks and Overall Research Plan

o Finalize and incorporate to the analysis the results for simulations driven with 1955-59 climatology (to asses GW/GHG contribution to total effect)

o Apply statistical analysis to the factor separation exercise, and to verify for significance of the differences found.

o Study the possible use various engineering and ecological parameters (e.g. Bowen ratio, Thermal Response Number) as indicators of regional/local environmental change.

o Extend the work to other Caribbean islands and tropical coastal regions.

o Perform simulations for different IPCC emissions-based climate change scenarios and future projections of LCLU change.

Acknowledgements

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